Masked Pneumothorax: Risk of Valveless Trocar Systems

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Purpose: Unlike traditional valved trocars, the valveless trocar maintains pneumoperitoneum during laparoscopy by forming a CO_2 curtain at the proximal end of the trocar. This gas barrier instantaneously maintains exact intraperitoneal pressure that yields to the transient physiological changes seen with breathing. Due to this different mechanism of action, pneumothorax development may be masked by the valveless trocar system.

Materials and Methods: We retrospectively reviewed 850 transperitoneal laparoscopic kidney and adrenal surgeries in which a valveless trocar system was used to determine any record of pneumothorax detected intraoperatively or postoperatively. A patient with pneumothorax was considered a case and anesthetic parameters were reviewed. A matched control group was generated from patients treated with transperitoneal laparoscopic kidney and adrenal surgery using the valveless trocar with no complications.

Results: Pneumothorax was diagnosed in 10 patients (1.2%). Two cases were the result of intentional excision of the diaphragm, which were repaired intraoperatively, while 8 were not recognized until the postoperative period. Five of the patients (63%) with unintentional pneumothorax required chest tube placement for a mean of 2.4 days. The remaining 3 patients (37%) were treated conservatively and followed with serial chest x-rays. The only anesthetic variable that was significantly different between the groups was Δ end tidal CO_2 with greater fluctuations in end tidal CO_2 in the pneumothorax group than in controls ($p = 0.03$).

Conclusions: Pneumothorax is a rare complication of laparoscopic urological surgery that is usually recognized intraoperatively through physiological changes. Valveless trocar systems mask these findings and can delay identification until the postoperative period.

Key Words: urologic surgical procedures, laparoscopy, pneumothorax, surgical instruments, iatrogenic disease

Abbreviations and Acronyms

ASA = American Society of Anesthesiologists
BMI = body mass index
$ETCO_2$ = end tidal CO_2
FiO_2 = fractional inspired O_2
HR = heart rate
MAP = mean arterial pressure
RR = respiratory rate

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LAPAROSCOPIC kidney and adrenal surgery has several advantages over open surgery, including decreased blood loss, less postoperative pain, and shorter hospital stay and convalescence.[1] A rare but well documented potential complication of laparoscopy is pneumothorax with an incidence of 0.4% to 0.7%.[2,3] When using traditional laparoscopic trocars, pneumothorax is often identified intraoperatively.[2,3] The signs of pneumothorax in this setting include diaphragm billowing as well as increased $ETCO_2$, peak airway pressure, RR and HR, and decreased O_2 saturation, mean arterial pressure and tidal volume.[3,4]

Recently, valveless trocars have been increasingly used in laparoscopic surgery. Compared to standard trocars,

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which simply pump CO_2 into the peritoneum, these valveless trocars maintain insufflation by creating and maintaining a pressure barrier. This is performed by recycling CO_2 gas into the proximal end of the trocar housing, filtering it and redirecting it back into the peritoneum to maintain a pressure barrier and insufflation. Benefits include improved visualization due to more rapid smoke evacuation during electrocautery, decreased laparoscope smudging, pneumoperitoneum maintenance during suctioning, and facilitated specimen and needle removal.[5] Investigation of its use demonstrated shorter operative time, a lower intraoperative CO_2 consumption volume and decreased CO_2 elimination.[6]

By keeping pneumoperitoneum at a consistent pressure, CO_2 is not pushed into the abdomen, which has the potential of masking the traditional signs of pneumothorax, which develops during laparoscopy with valved trocars. In our experience with the valveless trocar we noted an increase in pneumothorax that was undetected intraoperatively. Therefore, we examined whether any anesthetic factors could aid in the intraoperative detection of pneumothorax during laparoscopy with valveless trocars.

MATERIALS AND METHODS

From June 2009 to December 2012 a total of 850 laparoscopic kidney and adrenal surgeries were performed at our institution using a valveless trocar system. A single valveless trocar was used in each case. Pneumoperitoneum was maintained at a pressure of between 11 and 15 mm Hg during each procedure. Pneumothorax was identified in 9 cases of laparoscopic renal or adrenal surgery using the valveless trocar and in 1 case of robot-assisted laparoscopic kidney surgery. All pneumothorax cases were diagnosed by chest x-ray or as the result of intentional incision of the diaphragm.

Patient demographics, and intraoperative and anesthetic parameters were collected for each group. Patient demographics included age, sex, ASA score and BMI. Operative parameters included estimated blood loss, intravenous fluid given and operative time. Anesthetic parameters were collected for the beginning of the case, the maximum and minimum values, and the range during the case, and the value at the end of the procedure. Values were collected for $ETCO_2$, HR, RR, MAP, O_2 saturation, tidal volume, peak airway pressure and FiO_2.

For this retrospective, matched case-control study, a patient with pneumothorax was considered a case. Each case was randomly matched to 3 controls without pneumothorax by ASA score, procedure and BMI $\pm$ 5. Two patients did not have 3 matched controls. One laparoscopic nephrectomy case had only 1 match due to the case ASA score and 1 robotic partial nephrectomy case had only 2 possible matches due to the low volume of robotic cases.

The case and its matched controls were considered a blocking factor on analysis. Two-way ANOVA was used to test the difference in the explanatory variable between the pneumothorax and no pneumothorax groups with a blocking factor included in the model to control for matched cases. Statistical significance was considered at $p < 0.05$. Since this study was exploratory, we did not adjust for multiple testing performed. Statistical analysis was performed using SAS® 9.2. Institutional review board approval was obtained for this study.

RESULTS

There were 10 patients in the pneumothorax group and 27 matched controls. Cases and controls were matched for ASA score and procedure. The pneumothorax group consisted of 5 females and 5 males, while the control group included 6 females and 21 males ($p = 0.12$). The pneumothorax group had 8 patients with right operations and 2 with left operations, while in the control group 16 and 11 underwent right and left operations, respectively. This difference was not significant (Fisher exact test $p = 0.43$). In patients with pneumothorax vs controls mean $\pm$ SD age was 59.5 $\pm$ 17.9 vs 62.0 $\pm$ 14 years ($p = 0.75$), mean BMI was 28.5 $\pm$ 6 vs 29 $\pm$ 5.5 kg/m^2, mean estimated blood loss was 340 $\pm$ 301.7 vs 243 $\pm$ 165 ml (not statistically significant) and the mean intraoperative intravenous fluid given was 2,770 $\pm$ 1,341.7 vs 2,246 $\pm$ 903 ml (not statistically significant). The pneumothorax group had a statistically significantly longer mean operative time than controls (198.6 $\pm$ 75 vs 140 $\pm$ 48 minutes, $p < 0.01$).

Eight of the 10 pneumothorax cases (80%) were inadvertent, while in 2 an intentional incision was made in the diaphragm. Three of the 8 inadvertent cases occurred during laparoscopic partial nephrectomy, while 2, 2 and 1 occurred during laparoscopic radical nephrectomy, laparoscopic adrenalectomy and robot-assisted laparoscopic partial nephrectomy, respectively. All 8 cases of inadvertent pneumothorax were undetected intraoperatively. The 2 cases of intentional pneumothorax occurred during radical nephrectomy. In each case intentional pneumothorax was treated with intraoperative chest tube placement.

For 8 pneumothorax cases detected postoperatively the rate of collapsed lung was 10% to 100% on chest x-ray. Six of these 8 cases were diagnosed within the first 24 hours of surgery, while 1 and 3 were diagnosed on postoperative days 3 and 4, respectively. Five patients received chest tubes and 3 were treated conservatively. For the 5 patients with chest tubes, time to chest tube removal was 2 to 4 days (average 2.4). Average length of stay for all 10 patients was 6.3 $\pm$ 5.4 days. At the initial postoperative visit and all subsequent visits no patient had sequelae due to pneumothorax.

The table lists anesthetic parameters. The induction, maximum and minimum values during the case, change in each minimum and maximum value, and value at end of the case were recorded for the anesthetic parameters $ETCO_2$, RR, MAP, HR, O_2